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PORTLAND-ZEOLITE-CEMENT FOR MINIMIZING ALKALI-AGGREGATE EXPANSION

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ABSTRACT

The Authors give an account of the performance modifications induced in the blended cements by replacing the typical pozzolanas with their zeolitic counterparts: volcanic tuffs, after suitable grinding. The advantages of such a replacement in terms of minimization of alkali aggregate expansion and of strengths increase at long ages are discussed, emphasizing also the favourable influence of expansion abatement supplied by a previous thermal treatment of the zeolitic addition.
The improved strength progress is interpretated in terms of a higher reactivity of the zeolite minerals in comparison with that of the pozzolanic glass and the expansion abatement in terms of ability to incorporate high alkali amounts showed by the abudant amorphous hydrated silicate.

Introduction

The suitability of minimizing alkalis reaction with some siliceous constituents, sometimes present as impurities in the aggregates for concrete, has recently been the more to the fore in Italy, too, owing to certain concurrent factors. They are substantially: the increased cost of thermal unit, favouring the choice of technologies which cause an alkali rise in the clinker (1); the return of dusts in the kiln, for environmental protection, before their immission to stack, which interferes with alkalis removal; the progressive exhaustion of the quarries better studied from the geo-mineralogical standpoint and the consequent use of less investigated aggregates; the advantage of employing aggregates to be found at hand.

...ion due to the neoformation of an alkaline jellylike silicate can ..., as is well known (2), by partial replacement of Portland clinker ...ble active additions, such as: pozzolanas, fly ashes, blastfurnace ... In order to cut down expansion, without detriment to early ages ...(3), it is therefore imperative to carefully individuate the type ... of active addition.

...lt of a long and systematic investigation devoted to examining thorou... manifold aspects of the partial replacement of clinker with the zeo... unterparts of the true pozzolanas: the volcanic tuffs (4), we are ... to present a type of "pozzolanic" cement prepared by partial replace... clinker with those tuffs, which is definitely suitable for remarkably ...r indeed removing, if manufactured with thermal activated zeolitic ... the harmfull expansion even with high alkali clinkers (5).

...facture and technical performance of such a cement are described in ...r.

Experimental

... tuffs, collected in various National eruptive districts and different ... and content of zeolite minerals diffused in their matrix, have been ..., after suitable grinding, for partial replacement of Portland clinker. ...ical composition of the products used is reported in Tab.1. Pozzolanas ... 4 (leucitic type) and n. 6 (alkali-trachytic type) are the vitreous ...parts of Roman tuffs n. 1 and 3 (low and high Latium) and Neapolitan ...uff n. 5, respectively. Zeolite minerals amount has been calculated ...basis of water content. A detailed account of the mineralogical compo... and characterization of the above mentioned tuffs is reported in pre...pers (6), (7), (8), (9).

...ral gypsum has been added to a clinker (Tab. 1) having 395 m^2/kg Blaine ... area. The additions have been in turn ground until a 13 ± 4% residue ... on a 32 μm sieve. Then blended cements have been manufactured in la... by mixing the clinker with 10, 20, 40% of each addition, as it is ...er one hour's thermal activation treatment (1) at 500°C.

... ascertained, by means of the pozzolanicity test according to Italian ...lications (10), that all the blended cements prepared definitely belong ... pozzolanic type when clinker replacement exceeds 10%, the tests here ...ized have been performed.

... emphasizes the influence of each addition, thermally activated or not, ...e workability of fresh mix, determined as resistance to the flow of a ...r, according to ASTM C 230-80 Specification. The graphic design of the ...ts obtained indicates that moderate clinker replacements most of all ...ase the mixes workability, which, however, definitely decreases as re...ment increases. It is to be noticed also that zeolitic additions lower ...bility in a slightly higher way than the vitreous counterparts and that ...a workability goes slightly down again if the addition has been previou...ctivated.

TAB. 1

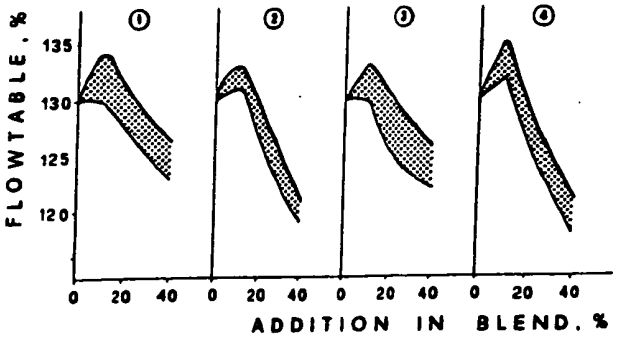
Chemical composition of the active additions (weight %)

Sample number		SiO_2	Al_2O_3	Fe_2O_3	CaO	MgO	Na_2O	K_2O	l.o.i.	zeolite type and content
1	tuff	42.0	15.9	9.0	13.0	4.0	0.5	5.4	10.1	chabazite+phillipsite 60%
2	pozzolan	43.3	17.4	9.0	13.4	3.9	0.5	5.9	6.5	----------
3	tuff	50.1	18.7	4.6	5.2	1.2	1.1	5.9	13.5	chabazite 50%
4	pozzolan	54.1	20.9	4.7	4.4	1.5	2.3	6.2	5.8	------
5	tuff	54.6	17.7	4.1	3.6	0.9	3.4	6.3	9.1	phillipsite 80%
6	pozzolan	57.0	18.3	4.5	3.1	0.9	4.1	8.0	3.7	------

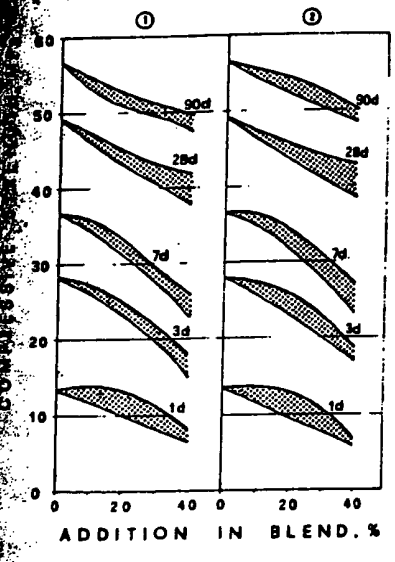
Clinker chemical and potential phase composition

SiO_2	Al_2O_3	Fe_2O_3	CaO	MgO	Na_2O	K_2O	SO_3	Na_2O eq.
21.3	3.6	4.5	65.3	1.0	0.7	1.7	2.1	1.8

C_3S = 63%; C_2S = 13%; C_4AF = 14%; C_3A = 2%.



Variation bands of flow values as a function of per cent addition. Mortars manufactured with blended cement containing: (1) pozzolanas, (2) activated pozzolanas, (3) tuffs, (4) activated tuffs.



Variation bands of compressive strength values as a function of per cent addition and curing period. Mortars manufactured with blended cements containing: (1) pozzolanas, (2) activated pozzolanas.

Fig. 2 and 3 answer for the results of the compressive strength tests on standard mortars (11) manufactured with pozzolan- and with tuff-cement samples. The graphic design of the data obtained, as a function of addition amount (activated or not) and curing period, emphasisizes the favourable influence of the zeolitic addition in terms of mitigation oh the long ages strength decrease, too. It is to be noted also that activation treatment of any type of addition does not effect very much compressive strength of the mortars.

Fig. 4 reports the results of potential alkali reactivity, performed on mortar prepared using Pyrex glass as aggregate, according [illegible] C 441-81 Specification. Data after six months curing show the remarkafluence of the zeolitic addition on expansion abatement. Such a positive ence is increased the more if the zeolitic addition has been thermally ated. After activation, the zeolitic addition in suitable amount in praremoves the expansion, in comparison with the Portland cement, whereas

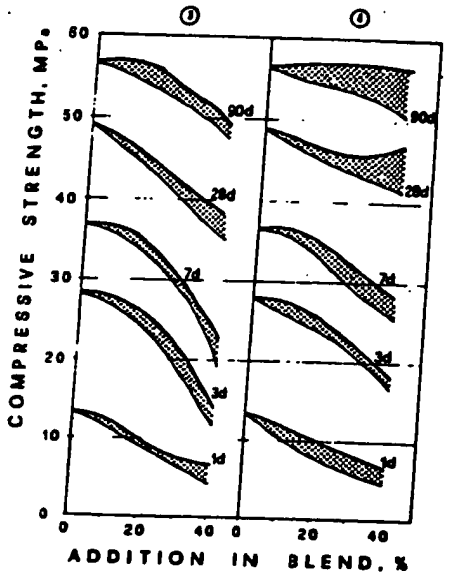


Fig. 3. Variation bands of compressive strength values as a function of per cent addition and curing period. Mortars manufactured with blended cements containing: (3) tuffs, (4) activated tuffs.

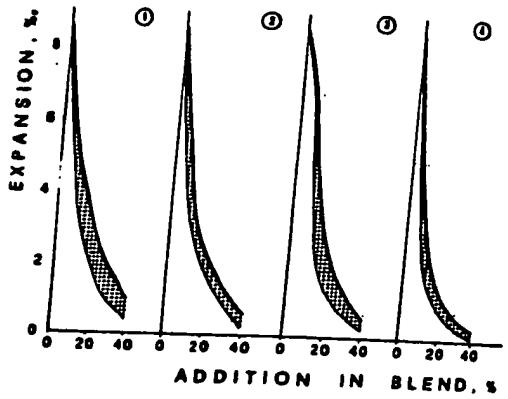


Fig. 4. Variation bands of expansion values as a function of per cent addition. Mortar bars manufactured with blended cements containing: (1) pozzolanas, (2) activated pozzolanas, (3) tuffs, (4) activated tuffs.

the same results can be reached adding a remarkably higher amount of vitreous counterparts.

Discussion and Conclusion

The whole of the experimental results indicate that the partial replacement of clinker with zeolitic additions allows the preparation of blended cements with technical performance better than that of the typical pozzolanic cements manufactured with the vitreous counterparts. Such an improved performance appears in terms both of compressive strength and of minimization of alkali aggregate expansion. Expansion appears moreover the lower if the zeolitic addition has been previously activated by one hour's thermal treatment at 500°C, whilst there is no evidence of such a further abatement after the same treatment of the vitreous counterparts.

At this point it is to be noted that the advantage related to the physical state of the typical incoherent pozzolanas, in comparison to the lithic zeolitic counterparts, is more apparent than effective, since energy consumption for grinding operation does not differ very much for both the products, owing to the peculiar fine-grained texture of the zeolitic tuffs (7). The grinding

of the two products demands in fact about 8-10 Kwh/ton, in compa- 30 Kwh/ton requested by the clinker, and the drying operation of or of a tuff, demands 200-250 Kcal/kg.

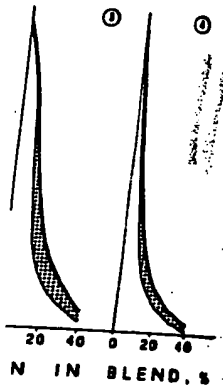
decrease of workability induced in the mixes by the zeolitic nature dition and the related higher water amount requested, does not in- he mechanical performance. Workability, in any case, can be suitably by means of water reducing agents.

and phillipsite, representing the main zeolitic minerals to be found, amounts, in the matrix of Italian volcanic tuffs, are definitely geable as active additions to Portland clinker.

resence of alkali reactive aggregates, zeolitic additions allow the on of clinkers with alkali content highly exceeding the Na_2O eq. t of ASTM Specification, according with the advancement of production ies.

ase of compressive strength, as well as the increased aptitude for xpansion due to alkali aggregate reaction, are both to be interpre- the basis of a higher reactivity of the zeolite products towards comparison with that of the vitreous counterparts. Owing to the pecu- stalline structure of porous solids exhibited by zeolite minerals, ic surface area wider than that of the bubbly pozzolanic glass is to the attack of alkaline solution, so favouring a more rapid and formation of the hydrated phases. A more rapid and complete Si-O- break, as a consequence of the attack of lime solution, causes, in he neoformation of abundant, low basic, amorphous hydrated calcium , which, favouring a more rapid compressive strength progress, can, ame time, incorporate remarkable alkalis amount, that otherwise would lable for fostering the dangerous expansion reaction.

her expansion abatement supplied by thermal activation of the zeolitic can in turn be interpretated on the basis of the following concurrent the formation of free bonds at the surface of the solid, owing to volution from its pores and channels; a sort of mobilization of the species due to the collapse of the crystalline structure; the wide surface are induced in the neoformed amorphous system by the originary line structure of the porous solid.



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